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ABSTRACT

The reasoning of adolescents in indeterminate situations was examined with particular attention given to how individuals incorporate the possibility that outcomes are determined jointly by more than one variable. Kuhn and Brannock's (1977) plant problem and two other similarly structured problems were administered to 25 inner-city adolescents ranging in age from 15 to 17 years. Each problem consisted of four cases for which the values of treatment variables and outcomes were described in detail. For each problem, subjects were asked to consider a fifth case, predict the outcome, and justify the prediction. In addition, subjects were questioned on the relevance of a variable which did not covary with outcome and the original procedure of the plant problem was modified by the introduction of a countersuggestion probe. In 73 percent of the overall justifications, subjects avoided the assumption that one variable independently determined the outcome. Five types of justification were found, and four of these demonstrated a concern with the determination of outcomes jointly by more than one variable. In particular, subjects supplemented their comparison and record arguments with covariation arguments. Implications for science education are briefly suggested. (RH)

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Justification of predictions: an analysis of alternative arguments.*

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Introduction

This study examines the reasoning of adolescents and is motivated by concerns which ultimately relate to the development of formal operational reasoning. Some studies have been concerned with subjects' use of the principle of covariation to isolate a single variable as independently determining the outcome of a number of situations involving several variables. However, real situations are often determined by combinations of variables and it often even appears naive to consider the outcome as determined by a single variable. Therefore, we would expect that the way people make sense of many real situations takes into account the determination of the outcome jointly by several variables. Furthermore, we specifically expect this to be so even when people do not have sufficient information to make unambiguous inferences as to the effectiveness of individual variables, and particular combinations of them.

Inhelder and Piaget (1958) have shown that, in determinate tasks which allowed the experimental testing of each variable while the others were excluded from the situation, systematic investigation of the effectiveness of individual variables preceded developmentally the systematic

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investigation of the effectiveness of combinations of variables. On the other hand, indeterminate situations may be more appropriate for examining the relative concern for combinations of variables as opposed to single variables. Accordingly, this study sought to examine how people reason in indeterminate situations. In particular, how do they incorporate the possibility that the outcome is determined jointly by more than one variable?

A research paradigm which allowed us to investigate these questions was introduced by Kuhn and Brannock (1977). These investigators devised a research problem known as the plant problem, in which subjects were given information about four separate plants. The problem is depicted in Figure 1 of your handout. For each plant, they were told how the plant was treated (how much water it got, whether or not it was given leaf lotion, and what type of food it got) and what the outcome was (whether it was healthy or not). The subjects' task was to predict the outcome of a fifth case. For the purposes of the present study, the interesting feature of this problem was its indeterminate nature. That is, the four cases presented do not allow a person to conclude unambiguously whether the outcome was determined by a single variable or whether it was jointly determined by a combination of variables. However, one variable, the type of plant food, does covary with outcome over the four cases. Therefore, if the subject was willing to assume that the outcome is determined by a single variable independently of the values of

other variables, then they can identify the type of plant food as the effective variable, and can exclude the other variables (that is, identify them as ineffective). Thus, this problem seemed particularly suitable for investigating people's concern for the determination of outcomes by a combination of variables rather than independently by a single variable.

Method

In the study I am presenting today, we gave the plant problem and two other problems similar in structure to 25 inner city adolescents, in the age range from 15 to 17 years. The two additional problems are shown on the figure in your handout. Each problem consisted of four cases, for which the values of treatment variables and the outcome were specified. The subject was asked to predict the outcome of a fifth case. The problems were presented in the same order to each of the subjects, with the plant problem first, the product problem second, and the tool problem last.

As mentioned, in the plant problem the outcome was whether the plant was healthy or not, and the variables were quantity of water, (large or small), type of plant food, (light or dark), and leaf lotion (present or absent).

In the product problem, the outcome was whether an unspecified product was improved or not, and the variables were various unspecified substances used in making this product. We hypothesized that the use of unspecified variables denoted by arbitrary symbols might encourage a more

specific consideration of each variable individually. For this reason, the substances were symbolically denoted by letters of the alphabet.

In the tool problem, the outcome was whether a machine was successfully fixed or not, and the variables were the tools available to a repairman. In the plant problem, the subjects, based on their everyday knowledge, are likely to consider water necessary for a healthy plant, and this might interfere with the identification of plant food as the single effective variable even though the plant food covaries with the outcome. However, no similar interference is apparent in the tool problem. We wanted to test whether this difference would lead more subjects to consider a single variable as effective in the tool problem.

In each problem, the experimenter described each case in detail to the subject, and then presented the subject with a fifth case in which only the values of the variables were specified. The subject was asked to predict the outcome of this case and to justify the prediction. Next, the subject was questioned on the relevance of a variable which did not covary with outcome, (that is, a variable which had the same value in cases with different outcomes and different values in cases with the same outcome). We modified the original procedure of the plant problem by introducing a countersuggestion probe. I will explain this part of the procedure later on.

Results and Discussion

Justifications of predictions

I will present today an analysis of the justifications that subjects gave for their predictions. In view of the time limitation, I will not refer to the responses to the exclusion probe, and will refer only briefly to the responses to the countersuggestion probe.

Most subjects predicted a positive outcome across all problems (83% of all responses). However, they used different types of argument in justifying their predictions: we refer to these as covariation, comparison and record arguments. About 17% of the overall responses were not categorized in this scheme. The relative frequencies of the arguments for each problem is shown in Table 1 of your handout. These types of argument were observed at various levels of completeness. Due to time limitations I will not elaborate on this point.

There was only one type of justification in which subjects identified a single variable as independently effective in determining the outcome. This was form 1 of the covariation argument, and only 9% of the overall justifications were of that type. As an example, subjects using this form of argument in the plant problem justified their predictions solely by reference to the covariation of the type of plant food with the outcome.

In contrast, in 73% of the overall justifications, subjects avoided the assumption that one variable independently determined the outcome. In fact, subjects used four different types of argument which demonstrated a concern with combinations of variables. I will briefly describe each of these types of argument.

1. In the second form of the covariation argument, subjects used the covariation with outcome of a combination of variables e.g., "some water and the light plant food" (in the plant problem), and "a screwdriver and the open wrench" (in the tool problem).

2. In the third form of the covariation argument, subjects used the covariation with outcome of a relationship between the variables. This was found only in the product problem, where, as already noted, letters were used to denote unspecified substances. Subjects using this argument based their justifications on the covariation of consecutive alphabetical ordering of the letters with outcome.

We have seen then that in these two last forms of the covariation argument, subjects used the principle of covariation but not to identify a single variable as independently effective. The next two types of argument that I am going to describe, specify other ways in which subjects demonstrated their concern with the effectiveness of combinations of variables.

3. In the record argument, subjects used the record of both variables present in the fifth case. The variables are considered one at a time and their records are ascertained, that is, whether or not they were present with positive or negative outcomes. And subjects' justifications were generated from a consideration of these records. This argument was mainly used in the product problem (78% of its occurrence). In this problem B and C were present in the fifth case. Typically, the subject pointed to the occurrence of B in cases with a good outcome, and to the presence of C both in a case with a good outcome and in a case with a bad outcome, and indicated that this meant that the chances were that B and C together would have a good outcome.

In this argument, subjects declined to predict on the basis of the perfect record of a single variable. Since subjects explicitly noted that C occurs with a good and a bad outcome, their evaluation of B must be interpreted as noting that B cooccurred only with the good outcome, that is, that B covaried with the outcome. Despite this, the subjects included in their justifications an evaluation of the record of the second variable present in the prediction case. Therefore, we see that even though the subjects perceived the covariation of a single variable with outcome, they avoided assuming that it was effective independently of the values of other variables.

In the record argument, subjects took into account the possibility of the joint determination of the outcome by more than one variable, but did not examine the effectiveness of

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specific combinations of variables. Since the experimental tasks did not provide complete information, this argument seems appropriate, providing a heuristic which yields a probabilistic judgment. In some of their responses subjects made the probabilistic nature of the argument explicit. For example, noting that variables B and C both are in cases with positive outcomes, whereas only one variable, C, is in a case with a bad outcome, subjects indicated that "that's two to one" in favor of a good outcome.

4. In the comparison argument, subjects used a comparison of the fifth case with one of the original cases (usually case 3). At the more complete level, subjects also explicitly referred to the difference between the cases and evaluated its relevance. For example, in the tool problem, some subjects indicated that the difference between the fifth and third cases was only the presence of the pliers. Then subjects judged the pliers as relevant or irrelevant and on this basis justified the prediction that the outcomes of the two cases would be the same or different.

It should be noted that subjects using the comparison argument base their justifications on a combination of variables. For example, by excluding the pliers in the third case, subjects determined the outcome of the combination of the remaining variables in that case. The usefulness of this type of argument increases, in fact, as the number of variables involved in a situation or task increases. This type of argument bears an affinity to what Rosch (1983) has

called reference point reasoning.

Summarizing the results so far, five types of justification were found, and four of these demonstrated a concern with the determination of outcomes jointly by more than one variable. While subjects mainly used the different types of argument separately, sometimes they combined them within one response. In particular, subjects supplemented the comparison and record arguments with covariation arguments. In these responses, it is clear that subjects perceive the covariation of a single variable with the outcome, but they do not consider it as sufficient justification for their predictions.

Comparison between problems

The predominance of the record argument in the product problem offers some support for the hypothesis that the use of unspecified variables encourages consideration of individual variables. However, the subjects' concern with combinations remained: namely, they did not assume that the variables were independently effective. On the contrary, in their justifications they combined the records of different variables. Similarly, the difference between the tool problem and the plant problem did not result in more subjects identifying a single variable as independently effective in the tool problem. For example, joint covariation with outcome of "a screwdriver and the open wrench" in the tool problem was not referred to less than "some water and light plant food" in the plant problem. The concern for the determination of

outcomes jointly by several variables rather than independently by a single variable transcends particular prior knowledge such as is available in the plant problem.

Responses to the countersuggestion probe

We have seen the different arguments in which subjects incorporate their concern for the effectiveness of combinations of variables. An important question remains as to whether or not this subjects are concerned with interactions between variables in a formal operational sense. The responses to the countersuggestion probe are relevant to this question.

Subjects who predicted a positive outcome (83%) were informed in the countersuggestion that the "actual" outcome was negative and were asked to explain that. This new information can be explained only by an interaction of the presented variables. For example, in the plant problem, it may be inferred that leaf lotion is not necessary for obtaining a healthy plant when there is a large glass of water but it is necessary when there is a small glass of water. Subjects noted this interaction in only 3% out of the 83% of the instances in which they were told that the actual outcome was negative.

A formal operational conceptualization of the original information would involve a flexible coordination of variables and the integration of the actual cases within a complete set of opposable possibilities. In other words, a formal approach

to the problem involves a system allowing identification of specific interactions, and flexibility between consideration of a single variable as independently effective and consideration of interactions. Therefore, the responses to the new information given in the countersuggestion show that the different types of argument that we observed, both those that identified a single variable as effective and those concerned with codetermination by a combination of variables, should not be considered as formal operational in character.

Summary

The justifications that subjects gave for their predictions showed that the subjects were mostly concerned with the determination of outcomes by a combination rather than independently by one variable. In only a few instances were the subjects concerned with the identification of a single effective variable.

The particular points to be made in conclusion are:

1. Even in the absence of formal operational, or systematic scientific reasoning, these subjects had a concern for the effects of combinations of variables, and they reasoned in a logical way which was not limited to some global and totally undifferentiated form.

2. Regarding the responses we have obtained as preformal in character, our interpretation is consistent with the view of a formal operational approach as developing from critical reflection involving a multiplicity of variables, even when testing the effectiveness of a single variable. (It involves

constructing the system of possibilities which gives meaning to the comparison between cases, the holding of all other variables constant while the effect of one variable is being tested.)

3. These considerations have educational implications, especially for science education. Some students do not consider the covariation of a variable with outcome as indicating that the variable is independently effective in producing the outcome. This seems related to a concern that the outcome is likely to be produced by several factors working together. Science courses often emphasize initially the critical role of one individual variable. The joint determination of outcomes by several variables is seen as a further degree of complexity to be introduced subsequently. However, our results show that at least some students are concerned with the joint determination of outcomes by more than one variable, even though these students do not take a formal approach allowing the identification of specific interactions from a system of possible combinations. In order to increase the meaningfulness of school science programs for these students, school science programs must be designed to capitalize on this concern while also facilitating the development of formal approaches.

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Justifications of predictions: An analysis of alternative arguments

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Figure 1.

The Experimental Tasks

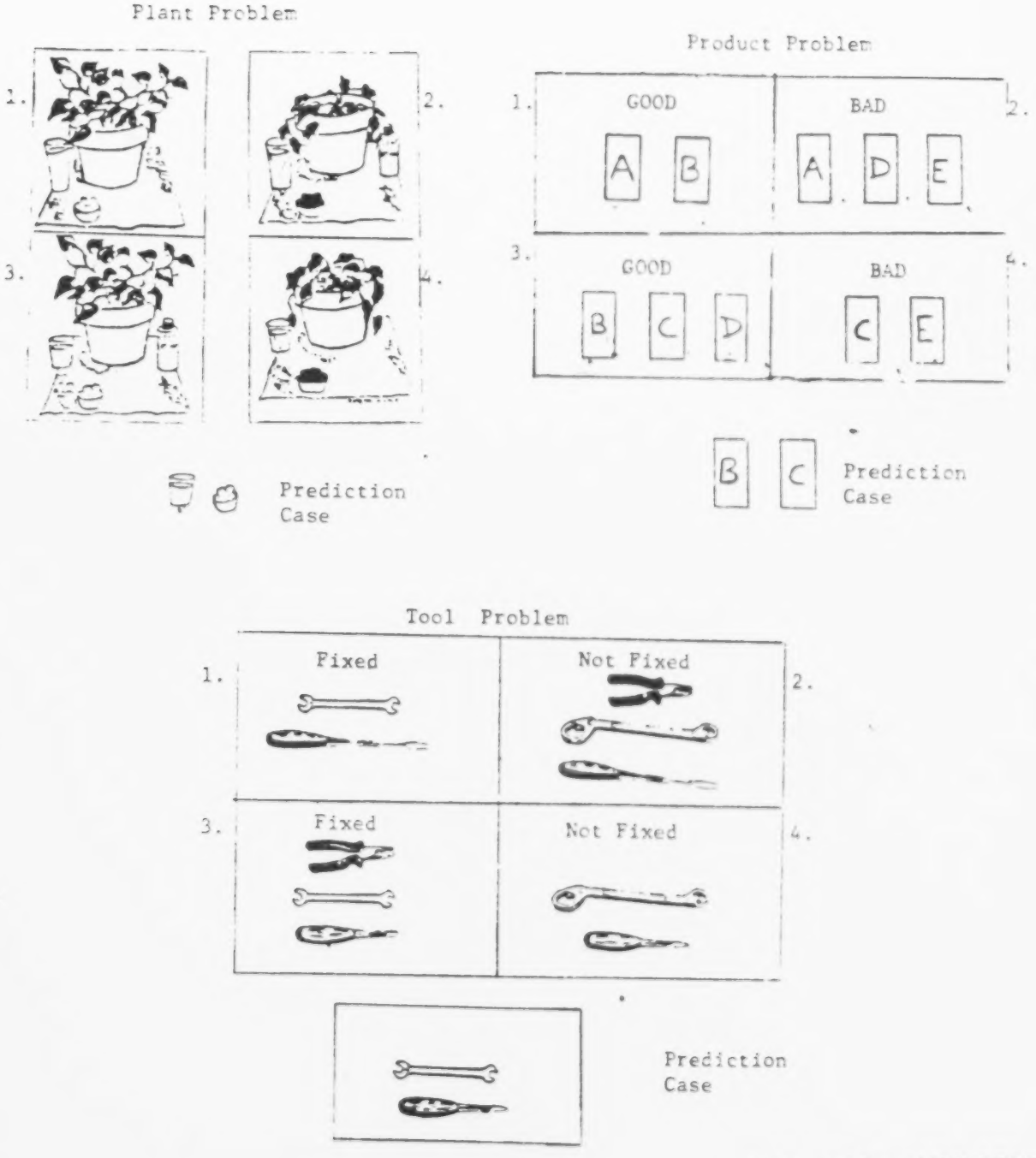

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Table 1

Percentages of subjects using argument types in the different problems

ARGUMENT TYPE	PROBLEM		
	Plant	Product	Tool
Covariation			
1. Single variable	20	4	4
2. Combination of variables	12	-	20
3. Relationship between variables	-	20	-
Record	-	28	8
Comparison	32	28	44
Combinations	12	12	4
Others	24	8	20